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EVALUATION OF SULFUR DIOXIDE INJURY TO VEGETATION ON FEDERAL LANDS NEAR THE ANACONDA COPPER SMELTER AT ANACONDA, MONTANA

by

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INTRODUCTION

The first copper smelting facility at Anaconda was constructed in 1884 for preliminary smelting of ores and in 1892 was enlarged for complete smelting. The basis of the current operation for producing anode copper was constructed in 1902 and included a huge smokestack nearly 600 feet high (Scheffer and Hedgcock 1955) (Fig. 1). During 1914 the smelter was processing nearly 10,000 tons of ore daily and was emitting about 2,500 tons of sulfur dioxide each day to the atmosphere (Mason 1915). This large quantity of sulfur dioxide was very toxic to vegetation and caused extensive damage to coniferous forests in the area. Mason (1915) reported that up to 9 miles distance from the smelter nearly all lodgepole pine (*Pinus contorta* v. *latifolia* Engelm.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) were killed by the fumes and that some damage up to 30 miles distant was found.

He grouped conifers common to the area by sensitivity to SO_2 in terms of mortality as follows:

1. Subalpine fir, *Abies lasiocarpa* (Hook) Nutt.
2. Douglas-fir
3. Lodgepole pine
4. Engelmann spruce, *Picea engelmannii* Parry ex. Engelm.
5. Juniper, *Juniperus occidentalis* Hook
6. Limber pine, *Pinus flexilis* James

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ROCKY MOUNTAIN STATION

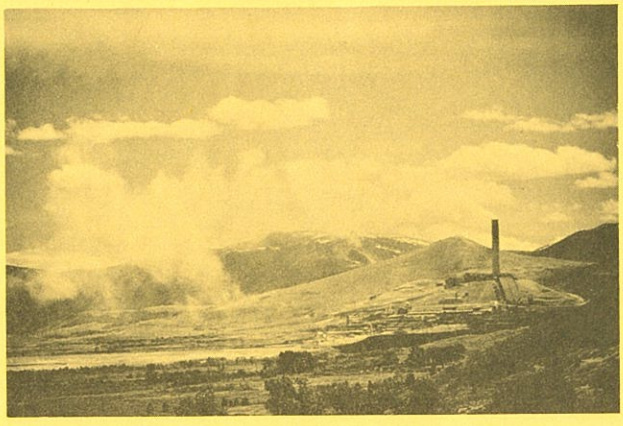


Figure 1.--Anaconda copper smelter at Anaconda, Montana. Note that despite the high stack, on this day the plume was looping to the ground less than one-half mile from the smelter. Injury to vegetation could occur on days such as this.

Scheffer and Hedgcock (1955) reported that in 1910-11 lodgepole pine, Douglas-fir, and subalpine fir were damaged up to 18, 20, and 22 miles from the smelter, respectively. Reproduction of conifers was very poor in the polluted area. Abortive cones were numerous, and even when seedlings became established, they would not survive for more than 1 or 2 years. Diameter growth of trees in the affected area showed a significant decline compared to similar stands in nonpolluted areas.

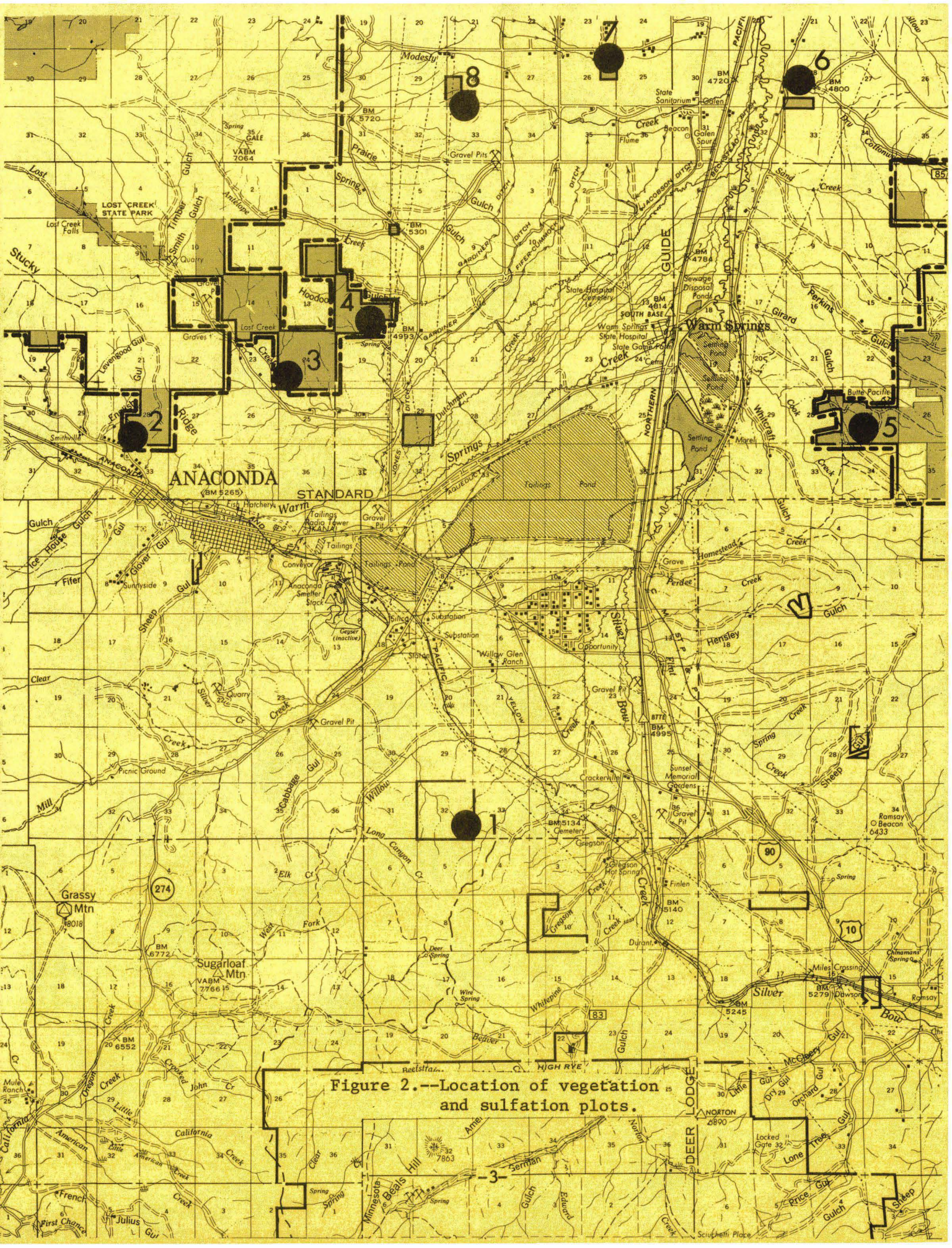
Since the early 1900's several SO_2 abatement devices have been installed to reduce the amount of the pollutant vented to the atmosphere. However, nearly 1,170 tons were still emitted daily in 1972. Introduction of a new sulfuric acid plant in 1973 reduced this to about 736 tons per day, and new SO_2 emission regulations promulgated by the State of Montana will allow less than 125 tons per day in the future.[1/]

A surveillance program to detect and evaluate air pollution damage to forested areas in Region 1, U.S. Forest Service, was initiated in 1969. This report documents the situation at Anaconda, Montana, as of summer 1972.

METHODS

Eight observation plots were established on U.S. Forest Service lands at varying distances from the smelter (Fig. 2). At each plot the flora

1/ Personal communication with Air Quality Bureau, Montana State Department of Health and Environmental Sciences.


ANACONDA
STANDARD
Warm Springs
Modesty
LOST CREEK STATE PARK
Lost Creek Falls
Stucky Ridge
Smithville
Fifer
Sunnyside
Glover Gul
Ice House Gulch
Sheep Gul
Clear Creek
Silver Cr
Picnic Ground
Mill Creek
Gabbage Gul
Willow Creek
Long Canyon Cr
Elk Cr
West Fork
Grassy Mtn
Sugarloaf Mtn
Crooked John Cr
Oregon Creek
Little California
American Creek
French Creek
First Chance
Julius Gul
Mule Ranch
Prairie Gulch
Timber Gulch
Antelope Gulch
Smith Gulch
Lost Creek
Hoodoo Gulch
Lavengood Gul
Dutchman Gulch
Jones Gulch
Warm Springs Creek
Tailings Pond
Anaconda Smelter Stack
Geyser (inactive)
Substation
Willow Glen Ranch
Yellow Creek
Bowl Creek
Silver Creek
Gregson Hot Springs
Gregson Creek
Crackerville
Sunset Memorial Gardens
Cemetery
Finlen
Durant
Deer Lodge
Norton
Locked Gate
Lone Tree Gul
Price Gul
Sheep Gulch
Scuthelli Place
Hensley
Homestead
Perdee Creek
Whitecraft Creek
Girard Gulch
Perkins Gulch
Butte Pacific
Northern Pacific
Chamamans Spring
Miles Crossing
Dawson
Ramsay
Beacon
Galen
Galen Spur
Flume
Beacon
Sewage Disposal Ponds
State Hospital Cemetery
South Base
Warm Springs State Hospital
State Game Farm
Cems
Settling Pond
Marell
Tailings
Gravel Pit
Quarry
Fish Hatchery
Radio Tower KANA
Conveyor
Substation
Station
Opportunity
Flint
Spring
Beaver
Wire Spring
Whitepine
Deer Spring
Reetstan
HIGH RYE
Norton
Locked Gate
Lone Tree Gul
Price Gul
Sheep Gulch
Scuthelli Place
Beals Hill
Minnesota
Amel
Norton
Sherman
Edward
Gulch
Creek
Spring
Ditch
Flume
Aqueduct
Jacobson Ditch
Gardner Ditch
Fifer-Dummon Ditch
Yellow Ditch
Sand Creek
California
Dry Gulch
Orchard Gul
McCleery Gul
Little Dry Gul
Bowl
Silver
Ramsay
Miles Crossing
Dawson
Chamamans Spring
Finlen
Durant
Gregson
Gregson Hot Springs
Gregson Creek
Crackerville
Sunset Memorial Gardens
Cemetery

present was examined for acute and chronic symptoms of SO_2 injury (Linzon 1958; van Haut and Stratmann 1970; Linzon 1972; Davis 1973).

Also, two sulfation plates (Huey 1968) were established at each plot to record ambient amounts of SO_2. These plates were changed twice during the summer, yielding two monthly readings at each plot in 1972 (Fig. 3).

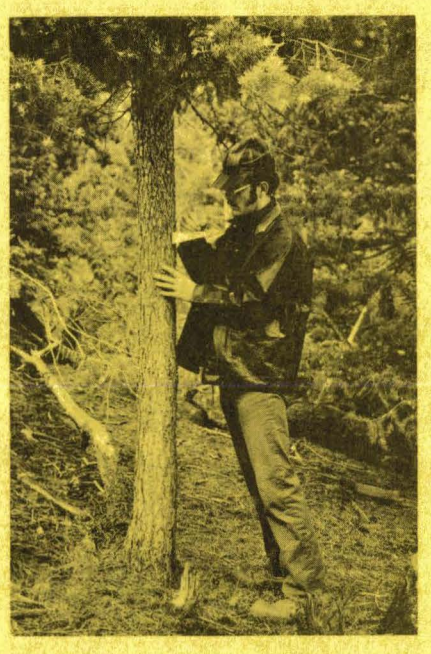


Figure 3.--Documentation of sulfation plate at plot 1. Don Berg, biology teacher, aided in this study.

A soil sample was taken at each plot and divided into three parts: duff, 0 to 2 inches below duff, and 2 to 4 inches below duff. Each fraction was analyzed for lead, cadmium, and zinc content at the University of Montana. The acidity of the 2- to 4-inch layer on plots 2, 3, and 4 was measured at the U.S. Forest Service Environmental Services laboratory in Missoula.

RESULTS AND DISCUSSION

Results of the injury survey, sulfation rate, heavy metal concentration and pH of soil are given in Table 1. In addition, direction and distance from the smelter and elevation of each plot is given. Symptoms of SO_2 injury were noted only at plots 2, 3, and 4. Injury at plot 4 was severe. Terminal dieback of Douglas-fir and limber pine was prominent and tip necrosis of foliage was abundant. The soil pH at these plots was low--normally one would expect it to be between 5.3 and 6.5. Soil acidity was not measured at the other plots. There was virtually no ground cover--less than 10 percent at plot 4. Soil was in an active state of erosion, roots of remaining trees were becoming exposed, and many trees were subject to windthrow (Fig. 4). It is believed that this condition was caused by high concentrations of SO_2 over the past 60+ years.

Table 1.--Results of several variables measured on Federal lands near the Anaconda copper smelter, 1972

Plot	Direction from smelter	Distance (miles)	Elevation (feet)	SO_2 injury	Species	Sulfation rate[a/]		Heavy metal concentration[b/]				pH of soil
						Sept.	Oct.	Layer	Pb	Cd	Zn	
1	SE	5.0	6,000	None	Douglas-fir, Ribes	2.2	1.1	Duff	270	10.5	331	
								0-2	304	10.8	320	
								2-4	130	6.9	208	
2	NW	4.5	5,300	Moderate	Limber pine	6.9	3.5	Duff	58	3.5	160	
								0-2	60	4.2	200	
								2-4	55	2.8	132	4.4
3	NNW	5.0	5,700	Light	Ribes, limber pine	4.6	2.4	Duff	62	3.8	138	
								0-2	55	2.9	112	
								2-4	58	2.5	128	5.3
4	N	5.0	5,400	Severe	Limber pine, Douglas-fir	4.3	3.2	Duff	67	2.4	166	
								0-2	60	2.5	218	
								2-4	80	.8	248	4.5
5	ENE	9.0	6,200	None	Douglas-fir	2.6	3.2	Duff	50	1.0	55	
								0-2	52	2.0	64	
								2-4	40	1.5	55	
6	NE	11.5	5,600	None	Douglas-fir	2.2	1.1	Duff	35	.8	60	
								0-2	30	.6	60	
								2-4	25	.8	60	
7	NNE	10.0	5,200	None	Cottonwood, Juniper, Douglas-fir	4.6	3.5	Duff	141	3.1	208	
								0-2	106	2.1	138	
								2-4	100	2.6	172	
8	N	8.5	5,300	None	Alfalfa	4.3	3.5	Duff	64	2.6	160	
								0-2	35	1.3	132	
								2-4	58	1.3	118	

a/ Micrograms $SO_2/cm^2/day$
b/ Parts per million

Figure 4.--Soils in much of the severely affected area are barren of ground cover. Severe erosion is occurring, causing surviving trees to fall.

Sulfation plates indicated that a considerable amount of sulfur dioxide is present throughout the valley. Concentrations were highest close to the smelter and northwesterly, northerly, and northeasterly therefrom. Control plates in another study indicate background levels should be near 0.0 ug/cm^2/day (Carlson et al. 1974). The State of Montana standard for SO_2 as measured by the sulfation plate method is 5 ug/cm^2/day for any 1-month period. This was exceeded only at plot 2 during September. However, because our plots were at considerable distance from the smelter (more than 4.5 miles), it is highly probable that this standard is constantly violated at closer distances.

Data on heavy metal concentrations in the soil is given only for information purposes. It was believed that very high concentrations, of lead, cadmium, or zinc would have an adverse effect on vegetative growth. However, it appears from the data that the injury observed was more related to sulfur dioxide that to heavy metal concentrations.

CONCLUSIONS

Sulfur dioxide injury to plants is still occurring on Federal lands near the Anaconda smelter. This injury is associated with significant quantities of SO_2 in the air. Even though the State of Montana sulfation standard was exceeded only on one plot during the survey period, damage was also found on two other plots where sulfation rates were less than the standard. Past SO_2 damage has resulted in deterioration of ecological systems at some locations to the extent that soil is currently eroding badly. It is questionable that land damaged to this extent will recover in the next century or longer. It is not known how much land is in this conditions now; a system of aerial photography combined with ground sampling would provide such information.

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